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Carbon stock accounting:

a report on progress in Australia and estimates of geocarbon

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1. INTRODUCTION

1. In order to effectively manage stocks and flows of carbon, it is important to have comprehensive information for policy development and analysis in this scientifically, economically and politically difficult area. At present, international reporting obligations for carbon relate to flow information for greenhouse gas (GHG) emissions, though these reporting obligations are motivated by a desire to limit the stocks of atmospheric carbon. The *System of Environmental-Economic Accounting 2012 – Experimental Ecosystem Accounting* (SEEA EEA) brings the accounting principles of completeness and integration to the reporting of carbon stocks and provides guidance in the compilation of carbon stock accounts.

2. This note reports on the development of indicative estimates of physical carbon stocks for Australia using the approach set out in the SEEA EEA. In particular, this paper presents preliminary results for carbon stocks in Australia's geosphere prepared by the Australian Bureau of Statistics (ABS). It is planned that these results will form part of a complete estimate of carbon stocks being led by the Australian National University (ANU). This note also describes the collaborative arrangements used for this work. It should be noted that the ABS already includes estimates of the value of fossil fuels in the national balance sheet of the Australian System of National Accounts (ABS cat. no. 5204.0).

3. Annexe 1 provides additional detail on the types of technical and measurement issues encountered in generating indicative estimates for carbon stocks in Australia.

2. CARBON STOCKS AND FLOWS IN SEEA

4. In developing its carbon stock accounts, the SEEA EEA has drawn from the *System of Environmental-Economic Accounting Central Framework* (SEEA Central Framework) approaches to accounting for stocks and flows. The SEEA Central framework briefly mentions carbon accounting, while a carbon stock account is articulated in the SEEA EEA (see Annex 2). This account records the carbon stock changes arising from human activities and natural changes in the carbon cycle (SEEA EEA, Fig. 4.1 and Table 4.6).

5. It is nearly 20 years since national governments first began investing substantially in information systems to meet their reporting obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. These systems were developed under Intergovernmental Panel on Climate Change (IPCC) guidance and generate considerable amounts of information. They are constantly being updated and refined. They are designed to report flow information, i.e. greenhouse gas emissions to and removals from the atmosphere.

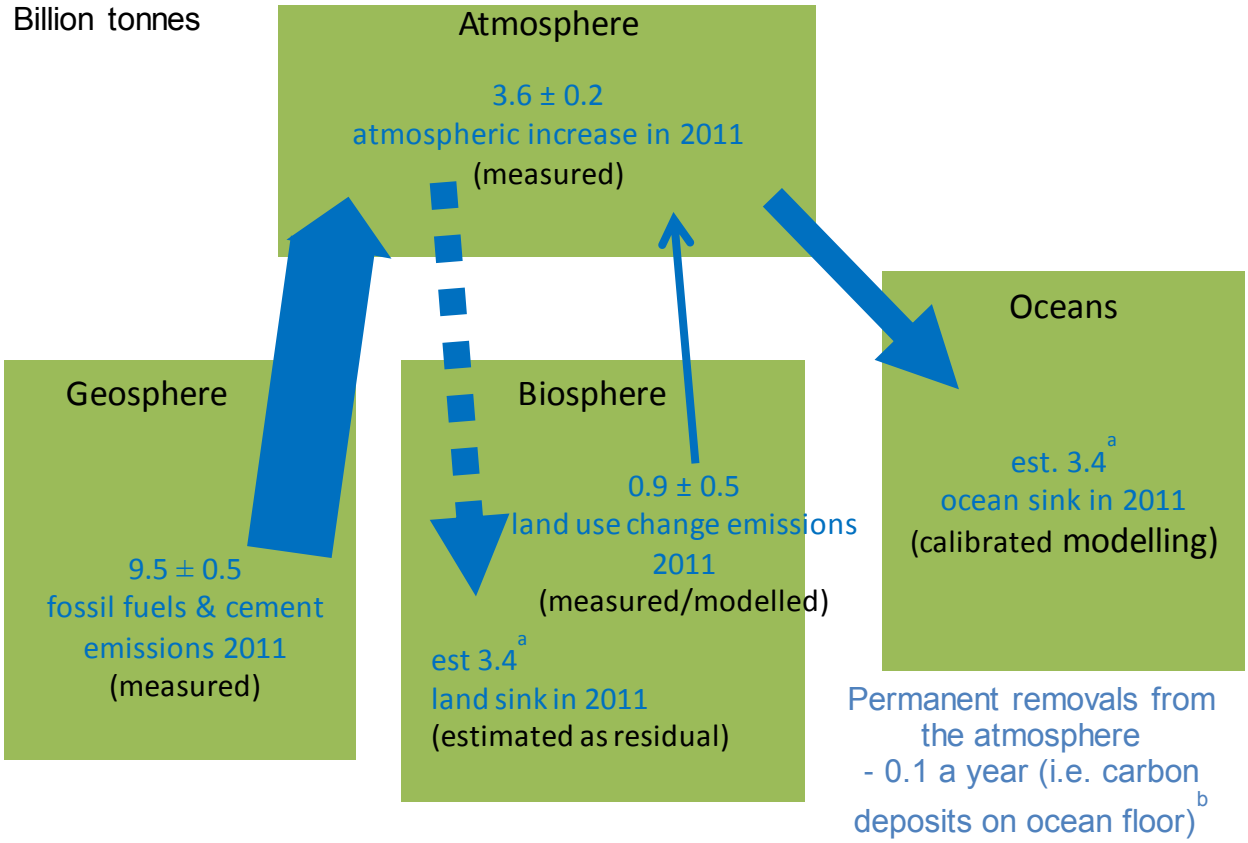
6. The carbon cycle sees carbon flow through and within the reservoirs[1]. Carbon is stored in the geosphere, the biosphere, the atmosphere and the oceans. The value of carbon stock and flow accounts in understanding the carbon cycle becomes clearer by taking a global systems perspective. From this perspective, the carbon cycle is a closed system: the amount of carbon is fixed and accumulations in one reservoir mean reductions in another (Mackey *et al.* 2013). Natural processes, which may occur over very long periods of time, and human activity over relatively shorter periods of time, work to change the size of the carbon stocks in the different reservoirs. Anthropogenic and non-anthropogenic flows take place within and between these stocks, making up the global carbon cycle.

7. Figure 1 shows that, globally, an estimated 9.5 billion tonnes of carbon was emitted into the atmosphere from fossil fuel combustion and cement production in 2011 (Global Carbon Project). Recorded land use change—principally deforestation—generated additional emissions of an estimated 0.9 billion tonnes of carbon in 2011. These human perturbations combined with flows generated from previous anthropogenic and non-anthropogenic events, saw carbon stocks in the atmosphere and oceans increase, respectively, by 3.6 billion tonnes and 3.4 billion tonnes over the year 2011.

8. Carbon stock and flow information concerning the biosphere is incomplete. Non reported flows have been estimated as a residual item (taking advantage of the fact that the global carbon cycle is a closed system and therefore must 'balance'). The residual item is large, approximately equal to the entire increase in atmospheric concentration of carbon in 2011. Houghton (2007) points out that the practice of calculating the flows for the biosphere as a residual could mask errors in measuring carbon stock changes for the land sector or in the ocean modelling. Further, although the residual item is in aggregate a large sink, it may also mask substantial emissions or removals in any (or all) reservoirs by anthropogenic or non-anthropogenic drivers (i.e. emissions or removals that fully or partially cancel out).

[1] Defined by the IPCC (http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf) as a component of the climate system, other than the atmosphere, which has the capacity to store, accumulate, or release a substance of concern (e.g., carbon). Oceans, soils and forests are examples of reservoirs of carbon. The absolute quantity of substance of concern, held within a reservoir at a specified time, is called the stock.

Figure 1 Global carbon flows



a. Applying reported removals of anthropogenic emissions by natural sinks during 2002-2011, in percentage terms.
b. Estimated by Freely *et al*. 2004 as a long term annual average.

9. Stock information in respect of carbon in the biosphere is important because the different qualities and management of the carbon reservoirs determines how easily carbon may move from the biosphere into the atmosphere and elsewhere. For example, carbon in natural vegetation is generally more stable than carbon in modified landscapes.

10. The SEEA EEA recognises these points (see paragraphs 4.98 to 4.101) and a feature of the proposed carbon stock account is that it has the capacity to show the dynamics of the carbon in the biosphere in terms of the reversibility, long term management (or 'controllability') and variability of emissions associated with the stocks. In this it is important to recognise that the dynamics of the biosphere reservoirs of carbon are more complex, from other reservoirs. The dynamics of carbon in the biosphere are heavily influenced by land use and land management practices, and the capacity to link

carbon stock accounts to land accounts (and spatial units more generally) is a potential analytically valuable aspect of carbon stock accounting.

11. At present there are a range of policies that target the biosphere for achieving atmospheric carbon goals. The potential for the biosphere to influence levels of atmospheric carbon is directly linked to the quantum of carbon potentially stored in that biosphere and the manner (i.e. quality) of this storage.

2. DEVELOPING CARBON STOCK ACCOUNTS FOR AUSTRALIA

12. The ANU via the HC Coombs Policy Forum has led the initiative to develop more comprehensive carbon accounting to support policy development in Australia. In this they have worked closely with the ABS and the Department of Environment (DoE). The ANU, ABS and DoE (then the Department of Climate Change and Energy Efficiency) met in November 2012 and established a partnership for a project with the following objectives:
    a. To identify the need for carbon stock information and potential data users.
    b. To undertake an experiment to populate the *SEEA* carbon stock account and in so doing identify research and information priorities, and further refine the account classifications, terminology and methods.
    c. To present recommendations to the Australian Government and UN Statistics Division aimed at improving the accounting methodology and information quality.
    d. To assess what is needed for regularly producing a carbon stock account for Australia.

13. Subsequent to the initial meeting, the further objective of understanding the current information sources and the methods behind the data sources was added.

14. Good progress has occurred against the first two objectives. This paper is evidence of this progress. A more comprehensive paper is planned and should provide the focus for a workshop on carbon accounting. Specifically the workshop is intended to explore issues related to:
    - the need for carbon stock and flow information;
    - the SEEA carbon stock framework;
    - estimating geocarbon;
    - estimating biocarbon;
    - statistical units and classification issues; and
    - linkages to the Australian Greenhouse Emissions Information System (AGEIS), Australia's National Carbon Accounting System (NCAS) and the economic and environmental information held by the ABS and other institutions.

3. PRELIMINARY ESTIMATES OF GEOCARBON STOCKS IN AUSTRALIA

15. Table 1 presents preliminary estimates of geocarbon, shown in the context of biocarbon and total carbon stocks. Estimates for biocarbon are in preparation but are not yet ready for publication and hence the cells are blank. The intention is to populate this table or one similar.

16. The development geocarbon and biocarbon estimates are important for two reasons. The first is that the experience has helped to identify a range of the tasks needed to complete the detailed accounting framework and methods. For example, to find relevant researchers, to identify and understand existing information and their ability to help populate a carbon stock account. Once complete, the estimates of biocarbon and geocarbon will provide an indicative picture of Australia's stocks of carbon. It is anticipated that these indicative estimates will enable potential users of carbon stock information to provide focussed feedback to support further refinement of carbon stock accounts and the linking of these to other information to support policy analysis.

17. In generating the estimates, the following factors have been considered:

- The 2008 SNA and SEEA Central Framework principle of completeness (meaning for this exercise, including all fossil fuel stocks, and all biocarbon stocks in the Australian territory, including marine ecosystems);
- Testing the feasibility of adopting an ecosystem type classification (natural, semi-natural, agricultural and settlements) given the strength of its scientific underpinnings, its policy relevance and the encouragement *SEEA Experimental Ecosystem Accounting* gives to incorporating the reservoir quality differences in its accounting framework;
- Identifying existing data sets produced by key Australian government agencies, particularly the DoE, for information to populate the account; and
- Identifying researchers who actually measure carbon stocks in natural or agricultural ecosystems in Australia and who have knowledge about particular ecosystems, how they function and the factors generating stock changes.

18. Annex 1 provides more details of the types of issues encountered in generating the preliminary estimates.

Table 1. Preliminary estimates of geocarbon stocks in Australia's (million tonnes C).[a]

Primary reservoir	Geocarbon Tonnes Carbon (million)	Hectares (million)	Biocarbon Tonnes Carbon (million)		
			Biomass carbon	Soil organic carbon	Total Biocarbon
Geocarbon					
Fossil fuel					
Black coal	242300[d]				
Brown coal	278500 [d]				
Crude oil[b]	146				
LPG[c]	91				
Natural gas	1629				
Shale oil	82864				
Total fossil fuel	**605530**				
Carbonate rocks					
Limestone	n.r.				
Other carbonate rocks	n.r.				
Total carbonate rocks	n.r.				
Other (includes methane clathrates)	n.r.				
Biocarbon					
Natural ecosystems					
Rangelands		596.3	X	X	X
Non rangelands:					
Eucalypt native forests		16.7	X	X	X
Shrub lands & woodlands		14.7	X	X	X
Grass, shrub & heath lands		1.6	X	X	X
Rainforests		2.3	X	X	X
Other		0.7	X	X	X
Marine ecosystems		1.8	X	X	X
Fresh water ecosystems		9.9	X	X	X
Total Natural ecosystems		**644.0**	**X**	**X**	**X**
Semi-natural ecosystems					
Highly modified rangelands		50.0	X	X	X
Grazing in modified pastures outside rangelands		32.9	X	X	X
Total Semi-natural ecosystems		**82.9**	**X**	**X**	**X**
Agricultural ecosystems					
Cropping		25.5	X	X	X
Irrigated agriculture		2.6	X	X	X
Plantation wood		2.4	X	X	X
Reservoir/dam		0.6	X	X	X
Other		6.3	X	X	X
Total Agriculture ecosystems		**37.4**	**X**	**X**	**X**
Settlements		2.6	X	X	X
Other		0.5	X	X	X
Total biocarbon		**3.1**	**X**	**X**	**X**

a. Coal estimates are for 30 June 2011. Oil and gas estimates are for 30 June 2009.
b. Includes naturally-occurring condensate.
c. Comprises LPG naturally occurring in crude and natural gas production fields.
d. Preliminary estimates currently being reviewed for possible improved carbon content factors.

19. Australian progress on carbon accounting is an example of implementation of the SEEA. The work is proceeding in a collaborative manner, with buy-in by academics and the key government policy agency. Such buy-in to the development of an information system is hopefully a predictor of its subsequent quality and successful use.

20. The proposed format for carbon stocks as presented in this note is considered sufficiently detailed to support a range of analytical uses. In particular, the breakdown of biocarbon stocks into natural, semi-natural and agricultural ecosystems is considered important to understanding and predicting the behaviour of these stocks.

21. With the budget pressures currently faced by public institutions throughout the world, it is encouraging that this work in Australia is moving forward rapidly in a collaborative manner, without the need for new data collections and at minimal additional cost.

5. QUESTIONS TO LONDON GROUP

- Have any other agencies begun work on carbon stock accounts?
- Are there important information sources that have been overlooked?
- What should the scope of physical carbon accounts be? (noting that the scope for the SNA is economically demonstrated resources)

6. ACKNOWLEDGEMENT

22. A large number of people have contributed ideas and support for this project. We would particularly like to thank: Mark Matthews (ANU, HC Coombs Policy Forum); Stephen Dovers (ANU Fenner School of Environment and Society); Ian Ewing, Bill Allen and Andrew Cadogan-Cowper (ABS) and; Rob Sturgiss (DoE). Judith Ajanis's work is supported by the HC Coombs Policy Forum of the ANU.

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ANNEXE 1: ISSUES IN THE MEASUREMENT OF GEOCARBON STOCKS FOR AUSTRALIA

A1. This annex describes the types of issues encountered in generating the geocarbon stock indicative estimates. A more detailed discussion of these issues is planned for a discussion paper for Australian stakeholders.

Geocarbon stocks in Australia

A2. The geocarbon stock estimates contained in this note are focussed on Australia's fossil fuel reserves: carbon in rocks, notably limestone deposits, has not been estimated. In estimating the carbon content of selected fossil fuel reserves, a consistent methodology has been used—with this methodology chosen principally on the criterion of data availability. It involves firstly estimating the physical quantities of various types of fossil fuels (billions of cubic metres, gigalitres etc.). These physical measures are then converted into a tonnes-equivalent, and finally an appropriate conversion factor is applied in respect of each type of fossil fuel to determine the carbon content, by weight, for each of these reserves.

A3. The discussion paper will pose a range of specific questions on the sources and methods used to estimate Australia's stocks of geocarbon. These questions will be designed to emphasise uncertainties and possible deficiencies in the estimates and to draw out expert views on how the estimates could be improved. The questions will range from those related to methodology to requests for any additional information that the authors are unaware of.

A4. The classification of existing estimates of geocarbon reserves in Australia is generally appropriate to our purpose, and is assisted by the fact that Geoscience Australia is responsible for physical estimates of the full range of Australia's coal and oil and gas reserves. Nevertheless, a number of questions arise, for example:

- Do we estimate carbon content of all fossil fuel stocks or just those that, under current conditions, are considered economically viable to extract?
- While the tonnage of coal reserves is readily available for Australia, the carbon content of coal by weight varies considerably between different types of coal. Thus, if a breakdown of black coal into anthracite / bituminous coal / sub-bituminous coal is not available from Geoscience Australia, can these proportions be modelled using partial data? For example, the World Energy Council estimates that sub-bituminous coal represents 5 per cent of Australia's economically demonstrated coal reserves (EDR) and in the absence of other information, the corresponding proportion for sub-economic demonstrated coal reserves (SDR) it assumed to be twice that reported for EDR.

A5. While the same basic estimation method has been used for all types of fossil fuel reserves, there are inevitably aspects for individual types of fossil fuel reserves that require a specific methodological response. For example, the retorting of kerogen from shale to produce 'shale oil' (synthetic crude, similar in character to crude oil) involves the release of

carbon to the atmosphere. However, the estimates in Table 1 above relate only to the carbon content of 'shale oil' ultimately resulting from the retorting process and do not incorporate carbon released from the shale reserve during the extraction process. This is consistent with say the extraction of coal where the carbon associated with extraction takes the form of such things as petroleum products combusted by extraction equipment—in which case the carbon content of these petroleum products has already been accounted for as part of oil and gas reserves. Contemporary methods of shale oil extraction differ from extraction of coal, and the carbon released during its extraction is more akin to the flaring of gas in oil and gas fields.

ANNEXE 2: SEEA EEA CARBON STOCK ACCOUNT (Table 4.5)

Gigagrams carbon (GgC)	**Geocarbon**					**Biocarbon**			**Atmosphere**	**Water in Oceans**	**Accumulation in economy**				**TOTAL**
	Lime stone	Oil	Gas	Coal	Other	Terrestrial ecosystems	Aquatic ecosystems	Marine ecosystems			Inventories *	Fixed assets	Consumer durables	Waste	
Opening stock															
Additions to stock															
Natural expansion															
Managed expansion															
Discoveries															
Upwards reappraisals															
Reclassifications															
Total additions to stock															
Reductions in stock															
Natural contraction															
Managed contraction															
Downwards reappraisals															
Reclassifications															
Total reductions in stock															
Imports and exports															
Imports															
Exports															
Closing stock															
*Excludes inventories included in biocarbon (e.g. plantation forests, orchards, livestock, etc)															